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XX. *Experiments and observations on electric conduction.* By WILLIAM RITCHIE,
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Read June 19, 1828.

THAT some substances conduct or convey the electric fluid to a distance better than others, is a fact known to the earliest electricians; but on what power or property of the body this superiority depends, is a question on which different opinions still seem to prevail. We constantly hear the expressions "electricity is attracted by metals; the lightning is attracted by the metallic points of a conducting rod," and other expressions of similar import,—all signifying that a powerful attraction does exist between metals and the electric fluid. Now the contrary is really the fact, those bodies being the best conductors which have the least attraction for the electric fluid. From the profound mathematical investigations of M. POISSON, and the luminous writings of M. BIOT, it appears that these philosophers consider the metals merely as forming the passive interior of a vessel, of which the exterior surface is the ambient air; and that the electric fluid rushes along between the atmospheric boundary and the surface of the metal, where it finds an easy passage. We are therefore to consider the metals as quite passive in the conduction of the electric fluid, and that the prime mover is the repulsive energy existing between similar atoms of the compound electric fluid. When a metallic ball connected with the earth is placed near the prime conductor, the vitreous electricity surrounding the conductor repels the vitreous electricity of the ball, and forces it to glide along to a greater distance, whilst the ball will now be surrounded by a thin film of the resinous fluid. The vitreous electricity of the conductor thus finding an easier passage in the direction of the ball, and being in a high state of tension, will, like every other elastic fluid, glide along in the direction of the ball as if it had actually been attracted by that body. The reason why it does not strike off with equal facility to a vitreous body is, not because it is less attracted by that body, but simply because it is unable to decompose with

the same facility the natural electricity belonging to the glass, on account of the powerful attraction existing between the atoms of the glass and those of the electric fluid. If the glass be thin and a metallic conductor placed in its interior, the vitreous electricity will act through the glass, decompose the fluid in the metallic conductor, and then actually strike through the glass in the direction of the metal where the resistance is least.

EXP. I. On the ends of two thermometer tubes I blew two balls of extreme tenuity. I then introduced two pieces of brass wire into the tubes till the ends reached within a small distance of the interior surface of the balls. Having brought the other ends of the tubes together, I joined them at the flame of the blowpipe, so that I had now a metallic conductor completely surrounded with glass. This being placed on a stand, and one of the balls brought near the prime conductor, I found I could take sparks, for any length of time, from the other end, in the same manner as if the glass had not been interposed. When the bulbs were about the thickness of those of a common thermometer, I observed that if sparks were taken for any length of time from the same place, they afterwards chose the same tract. I naturally concluded that the glass had been pierced, though I could not determine it by the naked eye. I found, however, that if the tubes were again separated and the air partially expelled from one of the balls by heat, and the open end of the tube placed in a vessel containing mercury, the mercury rose in the tube, but after a short time it again sunk to its proper level; clearly showing that the bulb had been pierced, though the aperture was extremely minute. I now began to suspect that in every case in which glass seemed to have been freely permeated by the electric fluid, that the fluid had been either silently conducted through it, or that, if carefully examined, it would have been found to have forced out some of the atoms of the glass. I therefore repeated the experiment with glass as thin as it could be blown without bursting, and found that the electric fluid would in that case freely permeate it; and that by no known method could I detect the smallest aperture in the glass.

EXP. II. Place an electric jar in a receiver, and partially exhaust the air; and the charge which can be given it will be very much diminished: exhaust the air still further, and it will be found impossible to communicate the slightest charge. In continuing to exhaust the air, the sparks between the ball con-

nected with the prime conductor and knob of the jar will become less and less till the electric fluid begins to flow in a continuous stream. From this experiment it is obvious that the jar ceases to receive a charge when the pressure of the air becomes equal or less than the repulsive energy existing between the atoms of similar kinds of electricity.

EXP. III. Place the Leyden phial in a receiver, to which is adapted a condensing syringe; condense the air, and the phial will receive a higher charge than in air of the ordinary density. In charging the jar, the sparks will be larger, and strike off at greater intervals than in common air.

It is quite obvious that in both of these experiments, the pressure of the air prevents the radiation of the electric fluid in the same manner as it acts in partially preventing the radiation of caloric from a heated body, or evaporation from the surface of water.

EXP. IV. Raise the end of an iron rod to a white heat, place the other end in either conductor, and the vitreous or resinous electricity will flow off to a metallic ball in a continuous stream. When the iron assumes a red heat, the current will change into a rapid succession of small sparks, which will increase in size as the iron cools. If the heated iron be presented to either conductor, the same effects will take place.

In this experiment the air surrounding the heated iron is highly rarified, and consequently exerts a diminished pressure on the electric fluid, which of course flows off by its own repulsion, exactly as it does in a receiver partially exhausted of air. The attraction of the iron for the electric fluid, when saturated with heat, will be diminished; and consequently the fluid will begin to flow off in a continuous stream, when the pressure of the air is greater than that of the air in a similar experiment in the exhausted receiver. When the iron has assumed a red heat, the surrounding air, not being so much rarified as in the case of a white heat, forces the electricity to accumulate in a small degree on the surface of the metal, and hence the commencement of the passage of the silent current into small sparks, exactly as it does in air of a certain density.

EXP. V. Raise the ends of two iron rods to a white heat, place them in the same line, with their heated ends at a considerable distance from each other; connect the cold ends with the opposite sides of a charged jar, and the jar will

be discharged by explosion, when the heated ends are at a much greater distance than it can be when the rods are cold. The air between the ends of the rods being partially rarified, will of course afford an easier passage to the electric current than air of the ordinary density, and hence the discharge will take place when the ends of the rods are more remote. This is exactly what takes place when cold rods are placed in a tall receiver partially exhausted.

EXP. VI. Place two metallic wires in the ends of a long pencil of flame formed by the blowpipe, connect them with the opposite sides of a charged jar, and the jar will be discharged by explosion along the flame. The spark will make its appearance at the point of the flame. The flame of a blowpipe is a hollow cone containing highly rarified air. The electric fluid will therefore glide along such a cone, exactly as it does along the interior of a hollow cone of glass partially exhausted of air. We are therefore not to regard flame as a conductor of electricity in the ordinary sense of the term; when the only part it performs in the conduction is merely that of forming a partial vacuum.

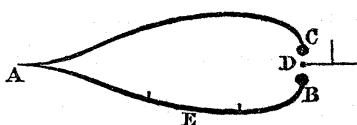
This fact is sometimes illustrated in a magnificent manner during violent irruptions of volcanic mountains. The air in the crater is highly rarified: and during a thunder-storm, the lightning is observed to dart into the hollow cone as if it were attracted by the flame, or by the mass of melted lava at the bottom of the crater; whereas the true cause of the phænomenon is found in the ready passage which the partial vacuum affords to the electric fluid driven off by its own repulsion from the charged cloud.

It is a well-known fact that imperfect conductors become tolerably good conductors when heated. Glass, for example, which is a very imperfect conductor when cold, conducts the electric fluid very readily when heated red hot. This is indeed what we might naturally expect from what we have assigned as the cause of conduction. Glass when cold has a powerful attraction for the electric fluid; it is therefore natural to expect that when charged with caloric, which is at least one of the ingredients of electricity, its attraction for that fluid would become less, and consequently afford a freer passage for the current along its surface. If the body be naturally a pretty good conductor of electricity, the ratio of its conducting power will not be so much increased by heat as in the case of a less perfect conductor. This at least was found by MARIANINI to be the case with fluid conductors; and from some experiments

which I have lately performed, I am led to believe that it will be found to be the case with every kind of conductor. Sir H. DAVY in some of his experiments on the conducting powers of metals, was led to conclude that the conducting powers of metals are diminished by heat, at least for voltaic electricity. It is perhaps true, that if a slender wire be heated in the middle by a spirit-lamp, the same quantity of the electric fluid will not find its way to the other end of the wire, as happens when the whole is cold. But unless the quantity of the electric fluid which escapes by the rarified portion of air surrounding the heated part be ascertained, no conclusion can be drawn with regard to the increase or diminution of the conducting powers of the wire.

In my experiments on the conducting powers of hot and cold iron, I very soon relinquished the use of wires for that of rods about half an inch in diameter.

EXP. VII. Let an iron rod be converted into the annexed form, in which C, B are brass balls, and A drawn to a fine point. Let a glass tube be A drawn out at a lamp to form a slender needle about six inches long, which is to be suspended by the middle by a fine thread of glass. Place two slender pieces of glass at each end of the horizontal needle, to prevent it having much motion. Twist the thread a little till the needle rest against the opposite supports. Place its pith ball D between B, C. Heat about a foot of A B in the middle, place the rod on an insulating support, with A near the prime conductor, and bring it rapidly to its former position. Turn the index till the attraction of B just overcomes that of C, continue to turn the machine, and the attraction of B will diminish so that the ball D will move off to C as the iron cools. From this experiment, it would seem that iron when heated is a better conductor of the electric fluid than when cold. The following experiment, which I have repeated at least ten times with uniformly the same results, will place this fact beyond the possibility of doubt.



EXP. VIII. Bring two brass balls connected with the earth near the balls B, C, (the part E being heated red hot,) till the electric fluid strike off almost equally to both; allow E to cool, and the electricity will cease striking off from B, and the whole will flow off in rapid sparks from C. The experiment may be rendered still more striking, by making the whole electricity at first

flow from B : as the iron cools, sparks will begin to appear between C and its ball, and in a short time the current will cease entirely from B, and the whole will now strike off from C.

As the ball B was at a considerable distance from E, its temperature remained uniform : we are therefore led to the conclusion that the electric fluid finds an easier passage along hot than cold iron ; or, to use the ordinary language of the science, iron when red hot is a better conductor of electricity than when cold.

Whether the cause of this be found in the diminished attraction which hot iron has for the electric fluid, in the diminished pressure of the ambient air, or in both causes combined, is a question which has not yet been solved ; but whatever be the cause, the fact is certain, though at complete variance with our preconceived notions on the subject, and even with the results of former experiments.

EXP. IX. Suspend a magnetic needle by the glass thread as in Exp. VII. Place a rod of iron heated white hot opposite either end of the needle, apply either pole of a horseshoe magnet to the other end of the iron, and the deviation of the needle both by attraction and repulsion will be found to be greatest when the rod reaches a red heat, and will continue to diminish as the rod cools. From this experiment it is obvious that iron at a red heat conducts the magnetic influence better than when cold. Though this experiment bears some resemblance to those of Mr. BARLOW, yet, as far as I know, the fact has not been previously observed ; and it affords us another striking analogy between the electric and magnetic influences.